The Mining Dynamics and Economic performance in South African Mineral Resources Using Quantile Regression

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Abstract

The paper analyses the performance of the South African mineral resources such as gold, coal, Platinum Group Metals (PGMs), iron ore, manganese and diamonds, by assessing the dynamics of commodity total production and sales over the period 1990-2018. The empirical evidence is based on Monge-Kantorovich Multivariate Quantile regression. The change in revenue, exchange rates, mining production oil prices, Producer Price Index (PPI) as well as the dummy variable which presents the shock of a global financial crisis, are proposed indicators of the study. The results are nevertheless ambiguous in some sectors. The findings provided that the depreciation of exchange rates is associated with positive and significant increases in total production and sales, particularly in the coal and diamond sectors. In particular, oil prices only contribute unfavorably to coal, PGMs and diamond production. The results might be interpreted to provide some useful implications for minerals and mining policy strategy.

Keywords: South Africa; Mining; Gold; Coal; PGMs; Iron ore; Manganese; Diamonds; Quantile Regression

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1. Introduction

The South African mining industry performance relies on certain aspects that ought to participate positively towards improving its output. In the past decades**,** the South African mining industry sector became one of the highest contributors to GDP value globally. Historically, South Africa's total reserves were once rated number one in the world followed by China in terms of gold production (Hartnady, 2009).

Despite the boom, periods occurred after the discovery of gold when the mining sector experienced severe challenges. In summary, historical sub period challenges include: Kimberly diamond strike (1868), Anglo – Boer war (1899-1902), First World War (1914-1918), Rand Rebellion in 1922, Second World War (1939-1945) and the Recession in 1980 (Department Minerals and Energy; 2008, South African History Online (SAHO) 2018). Recently, it was declared that approximately 75 % of South African gold mines are facing a major crisis of not making a profit. The preceding observation was due to the price of the commodity, fluctuating exchange rates, labour costs wage negotiations (Mining Council (2018) and RT International (2018)). In addition, in 2007 a strike took place in gold, platinum and coal mines due to demands for better and safer working conditions. The Lonmin strike that occurred in 2012 which took about 5 months was confirmed as the longest strike in the South African platinum mining history (LaFraniere (2007) and SAHO (2014)).

Therefore, this research paper will investigate the nexus between South Africa's total mining production output with the changes in sales, mining production oil prices, exchange rates, Producer Price Index (PPI) and the uncertain global financial crisis shock. More specifically, the paper will be assessing the dynamics of these recommended indicators towards enhancement of potential mining industry performance growth. In particular, this research intends to answer the questions: Does a change in mining industry revenue alter the total production output? Do the fluctuations in crude oil prices contribute to mining total output? How do changes in the exchange rate affect South Africa's locally produced mining output through its effect on the country's exports? How are increases in production costs in the mining industry associated with changes in total production revenue? Last, how did the global financial meltdown phenomenon alter the mining industry?

This current paper will touch base with well-organised topics that numerous articles have covered; however the topic of this article has not been efficiently addressed by other researchers. More specifically, the content of the study will outline multiple factors that ought

to deter the total mining output in South Africa, including the impact of the 2008 global financial crisis.

The following section of the study is organised as follows: section two is the literature review assessing the determinants of total mining output; section three presents the data and methodology employed by the study; section four presents and discusses the empirical results; then section five will be verifying the quality of the model; while sections six and seven present the concluding remarks and research recommendations.

1.2 The Overview of South African Mineral Resources

The mining sector has played an influential role in generating economic activities over the past decades. South Africa's economic history has been characterised by enrichment of mineral resources as diamond, gold, platinum, coal as well as other minor minerals such as chrome, vanadium and titanium. However, the study will pay more attention to gold, coal, PGMs, iron ore, manganese and the diamond sector.

1.2.1 Gold

In June 1886, the first gold mine was discovered on the banks of the Witwatersrand by Gerrit Banjies. Around that time, both gold and diamonds began to dominate the South African economy, taking over from the indigenous agricultural sector such that gold mining in South Africa became the largest producer in the world (Mining Council, 2018). In South Africa, the exploration of gold is found in three provinces; namely Gauteng, North West and Free State. Throughout these parts, there are several gold producers such as AngloGold Ashanti, Harmony, Sibanye-Gold Stillwater, Goldfields, Pan African Resources, Village and defunct operations.

Despite the growth, several challenges, which revolved around the political atmosphere, social factors and the global economic outlook, were confirmed. According to Neingo and Tholana (2016), some of the challenges included the global competition with countries such as Botswana.

1.2.2 Coal

In 1864, the first coal mine was founded in the Eastern Cape in the town called Molteno named after an immigrant, John Molteno. Then the dispersion began into other provinces, and in the late 1880s another commercial coal deposit was discovered in KwaZulu-Natal and Gauteng

provinces. More coal mining commenced in Mpumalanga, Limpopo and Free State provinces such that South Africa become the developing coal exporter globally. According to the Chamber of Mines South Africa (2018), the South African coal commodity accounts for almost 3.3 % of the world's output, which is equivalent to 30 billion tonnes (Mining Council, 2018).

1.2.3 PGMs

Geographically, the Platinum Group Metals (PGMs) are currently operating in nine provinces; namely Gauteng, Limpopo, North West, Mpumalanga, Free State, KwaZulu-Natal, Northern Cape, Western Cape and Eastern Cape such that South African PGMs hold over 80 percent of world reserves. Historically, the first platinum mine was discovered in 1924 and was known as the Bushveld Igneous Complex (BIC). During the time the platinum mine produced at least 75 percent of the world's total output. Despite the invasion of World War II, platinum mine production grew substantially and also new innovative technology operational initiatives had a meaningful impact in growing the mining industry. In 1960, the platinum commodity market saw an increase in global demands for jewellery which allowed the platinum producers to maximise their operating profits.

During the boom, in the 20th century, the major PGM producers produced almost 80 percent of the world's total output, and these were housed within the following groups: Implats, Amplats and Lonmin. This was due to an amendment of the Mineral and Petroleum Resource Development Act of 2002. This led to an increase in foreign investors' interest which was caused by high costs and increasing demand during the period 2002 to 2008.

1.2.4 Iron ore

The key iron ore sector players are BHP Billiton, Rio Tinto, Companhia Vale do Rio Doce (CVRD) and Kumba Iron Ore (KIO). Globally, other countries that produce iron ore include the United States, Iran, Russia, Australia, India, Brazil, Canada, China, Sweden and Kazakhstan Mining Africa (2017). The common challenges encountered by the key role players are costs associated with extracting the ore and transporting it. As a result, like any other mining sectors, iron ore mining also required intensive investments in capital and infrastructure to functionally outperform competitors. South African iron ore mines saw global growth since their establishment, such that about 663.6 million tons of iron ore are produced locally, which equates to one percent of the world's reserves.

Furthermore, in 2014, the South African iron ore sector produced about 78 million tons and exported a total of approximately 86 % to its largest importer which is China (Conradie, 2015). Among the challenges in this sector, energy and production costs have been the most common factor in the mining industry. In many emerging economies such as South Africa, which are faced by currency instability, producers will always strive to maximize operational profits.

1.2.5 Manganese

Predominantly, South Africa produces about 75 percent of the world's manganese output making it the second biggest producer in the world. Nevertheless, this commodity saw an evitable growth during the period 2001 to 2007, due to high demand mainly from China as well as other emerging exporters (DMR, 2018). to South African key producers include Kudumane Manganese Resources (KMR), a recently founded mine situated in the Northern Cape province in Hotazel, United Manganese of Kalahari (UMK) also located in the Northern Cape province operating at Mamatwan, as well as Wessels and Black Rock mines. Also located in the Northern Cape province, ASSMANG founded in 1940, operates Black Rock mines which domestically supply a portion of its output to KwaZulu-Natal province.

Located in the Northern Cape and operating in the Kalahari Manganese Field (KMF) is Tshipi é Ntle Manganese Mining Proprietary Limited. Tshipi is one of the largest manganese ore exporters in the world. South 32 is amongst the largest manganese ore mines in the world, also located in the Northern Cape operating in the Kalahari Basin. South 32 holds about 80 percent of the world's manganese ore store. Other emerging manganese producers include PMG, Sebilo, Kalagadi, Lidino and Emang.

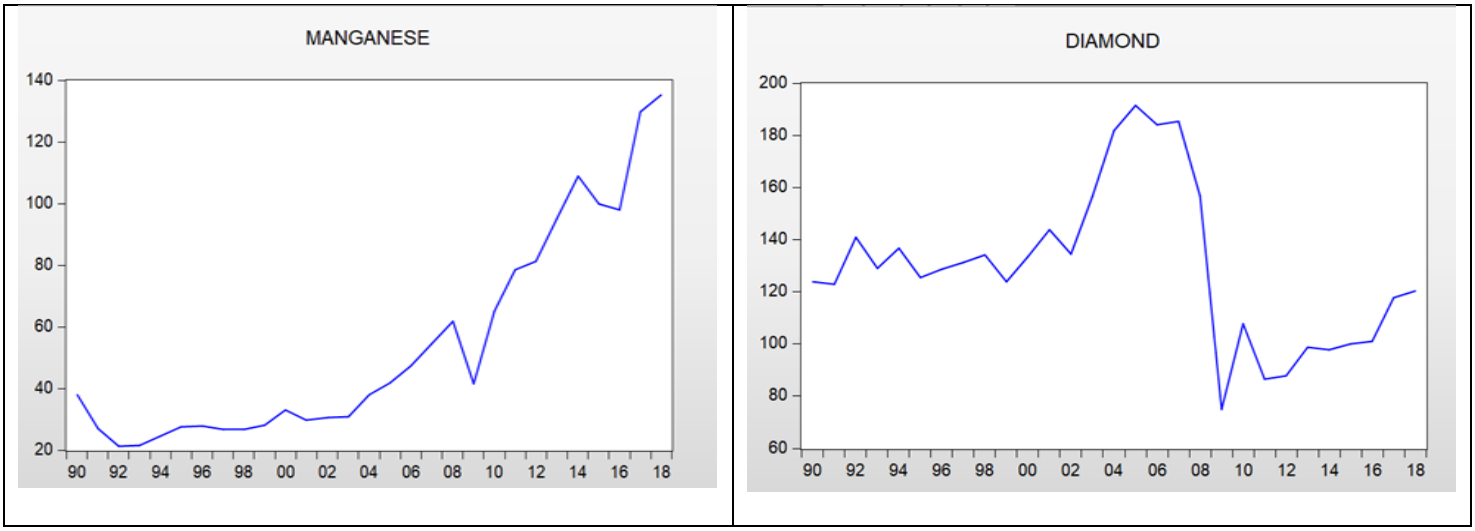
1.2.6 Diamonds

In 1867, the first South African diamond mine was discovered in the Northern Cape province outside Garies, not far from the town named Hopetown. Regardless of the strike that took place a year later, diamond mine production was about 21.25 carats. South Africa is responsible for the most remarkable portion of diamond production output around the globe. Despite the key challenges experienced in the diamond industry such as operational cost, lack of skills and labour related issues, diamond production saw an inevitable growth during year 2003.

According to the Mining Council (2018, during the growth phase, three diamond mines were discovered; namely Premier mine in 1905, Cullinan mine in 1902, Finsch mine in 1978 and

Venetia in 1992. During 2018 the South African total diamond mining production sales was about R16.3 billion.

Table 1: The trends analysis of Gold, Coal, PGMs, Iron ore, Manganese and Diamond production output in South Africa mining industry over the period 1990 to 2018.



Source: Stats SA (2018)

The graphical illustration of Gold, Coal, PGMs, Iron ore, Manganese and Diamond production output over the years 1990 to 2018 are presented above in Table 1. The gold trend exhibits a diminishing path from the value of 428.8 in year 1994 to approximately 81.1 in year 2018. It is argued that the most common reason for the declining gold volumes was due to the extinction of the high-grade commodity which meant that miners had to switch to lower-grade deposits. As shown, the coal production output trend exhibits an increase from 1990 to 2018 from 70.7 in year 1990 to 100.4 in year 2018. Along the study period, the coal production trend shows at least eight decline points and also eight increase peaks.

Moving to PGMs, the graph shows an initial increasing trend which then decreases. The PGM production output increases from 51.5 in 1990, reaching the highest value of 112.3 in 2006. Then from year 2007 it began to decrease gradually, reaching 104.9 in 2011. After that, the fastest decreasing rate occurred between 2011 and 2014 reaching the lowest value after the year 2000, of 68.4 in year 2014. Another expanding commodity is iron ore. As can be seen in the above graphical illustration, the iron ore growth rates increased from 36.1 in year 1991 until late 1999, then increased again at a moderate pace from year 2000 until early 2008. In 2009, the iron ore production growth output showed a strong growth rate compared to previous years such that iron ore output increased from 76 to the highest produced output of approximately 111 in 2014.

Manganese production, compared to the gold trend, has been characterised by an increasing total output from the period of discovery. As shown in table 1, the manganese trend increases below the value of 40 from 1990 to 2004. Then within a short period from 2005 to 2011, the total manganese output doubles in size. Surprisingly, from period 2012's total value of 80,

manganese's production output escalated to almost 136 in year 2018. The manganese output growth is strongly correlated with the total exports. This was due to new revival producers and increased demand in the market. Davies' (2018) article also confirmed that the total of 1.7 million tonsof exports has multiplied over the space of five years; however, in 2017 it was reported that almost 14.7 million tons of manganese were exported.

Lastly, the graphical trend for diamonds is also presented in Table 1. As shown, the diamond production output trend has been fluctuating amongthe value of approximately 131 over year 1990 to 2002. The diamond production output saw a strong growth rate from period 2003 to 2005, reaching the highest peak of 191.6. After that, the diamond mines saw an inevitable double digit decrease and some of the reasons included price instability, political influence and mainly economic problems such as the impact of the global financial crisis which took place in late 2007 (AGD Diamonds 2014). As a result, diamond production output reached the lowest vulnerable value of 75.1 in year 2008. Notwithstanding this, increased diamond prices as well as the increasing demand after 2010 led to the recovery of the global diamond industry, which contributed as a multiplier towards significant exports and production increases until the year 2018.

2 Literature Review

Smith (2004) reviewed the performance of diamond mining in Canada during the period 2001 to 2006. The study outcomes pointed out that labour productivity is an important element in the overall mining industry, therefore the mining industry in Canada will be outperformed in the absence of diamond mining. Wu and Lin (1992) investigated the nexus between money supply (MJ), real output, exchange rates, and price (CPI) using monthly data from 1981 to 1992. The outcomes provided that in the short run, an increase in money supply and depreciation in exchange rates have a positive impact on price, while an increase of real output has a negative effect. Kandil and Mirzaie (2005) carried out a study to assess the currency fluctuations in its relationship with exports, imports, domestic currency and aggregate supply, using the cost of intermediate goods. The results of the study indicated that depreciation in the exchange rate has a limited impact on output growth and price inflation across selected developing countries.

Another study undertaken by Cordova, Mobarec, Pizarro and Videla (2018) attempted to evaluate the major mining cost elements and identify the economic risks that are posed by these variables. The results from the Monte Carlo estimation model showed that both labour and

energy costs are the major contributors towards risk perspectives, so labour productivity and resource optimisation should be prioritised. Palavar's (2017) paper investigated the cost-efficiency optimising technique in South African mining industries and also examined the factors that ought to affect mining production. The study's results indicated that many mining industries strive to meet the efficiency criteria required such that many projects in mining industries pay more attention to cost reduction initiatives.

Fedderke and Pirou (1999) used the Vector Error Correction Model (VECM) to explore the relationship between economic output and employment over the period 1970 to 1999, focusing on three different mining sectors. The paper's results revealed that there is a positive significant correlation between employment as well as economic output. This means, in the gold and uranium mining sectors, the decreasing production output is associated with increasing labour costs. LaneI, Guzek and van Antwerpen's (2018) study analysed the uncertainty and social, economic and political risk that the mining industry encounters. The paper confirmed that the mining industry should adopt an innovative culture, because a sustainable long term strategy, cost optimisation as well as capital allocation are important to attract investment and growth in total output.

3 Data and Methodology

The study makes use of annual data collected from Federal Reserve Economic Data (FRED) (2019) and Statistics South Africa (2018) databases for selected indicators from 1990 to 2018. The selected response variable includes: Gold, Coal, PGMs, Iron Ore, Manganese and Diamonds. Then the predictors will consist of changes in sales, oil prices, exchange rates, Producer Price Index in mining and shock of the global financial crisis as a dummy variable.

The paper will specify its models as follows:

Model 1: Gold total production and Sales

$$GoldOuput_{it} = \beta_0 + \beta_1 \Delta Sales_{it} + \beta_2 Oilprice_{it} + \beta_3 Exchangerates_{it} + \beta_4 PPI_{it} + \beta_5 DVGFC_{it} + \varepsilon_{it} \quad (1)$$

Model 2: Coal total production and Sales

$$CoalOuput_{it} = \beta_0 + \beta_1 \Delta Sales_{it} + \beta_2 Oilprice_{it} + \beta_3 Exchangerates_{it} + \beta_4 PPI_{it} + \beta_5 DVGFC_{it} + \varepsilon_{it} \quad (2)$$

Model 3: PGM's total production and Sales

$$PGM'sOuput_{it} = \beta_0 + \beta_1 \Delta Sales_{it} + \beta_2 Oilprice_{it} + \beta_3 Exchangerates_{it} + \beta_4 PPI_{it} + \beta_5 DVGFC_{it} + \varepsilon_{it} \quad (3)$$

Model 4: Iron Ore total production and Sales

$$IronOreOuput_{it} = \beta_0 + \beta_1 \Delta Sales_{it} + \beta_2 Oilprice_{it} + \beta_3 Exchangerates_{it} + \beta_4 PPI_{it} + \beta_5 DVGFC_{it} + \varepsilon_{it} \quad (4)$$

Model 5: Manganese total production and Sales

$$MangOuput_{it} = \beta_0 + \beta_1 \Delta Sales_{it} + \beta_2 Oilprice_{it} + \beta_3 Exchangerates_{it} + \beta_4 PPI_{it} + \beta_5 DVGFC_{it} + \varepsilon_{it} \quad (5)$$

Model 6: Diamond total production and Sales

$$DaimondOuput_{it} = \beta_0 + \beta_1 \Delta Sales_{it} + \beta_2 Oilprice_{it} + \beta_3 Exchangerates_{it} + \beta_4 PPI_{it} + \beta_5 DVGFC_{it} + \varepsilon_{it} \quad (6)$$

Where, $GoldOuput_{it}$, $CoalOuput_{it}$, $PGM'sOuput_{it}$, $IronOreOuput_{it}$, $MangOuput_{it}$, and $DaimondOuput_{it}$ are response variables (y). β_0 is the slope of the model and the intercepts are $\beta_1 \Delta Sales_{it}$ (Change in Sales), $\beta_2 Oilprice_{it}$ (Global oil prices), $\beta_3 Exchangerates_{it}$ (Exchange rates), $\beta_4 PPI_{it}$ (Producer Price Index), $\beta_5 DVGFC_{it}$ (Global financial crisis Dummy variable) and ε_{it} is an error term of the model.

The paper will provisionally employ the Quantile regression (QR), as introduced by Koenker and Basset (1978) which may be considered an extension of the Classical Least Squares (CLS) estimation of conditional mean models to the estimation of a set of conditional quantile functions. Quantile regression allows the estimation of the conditional quantiles of a response variable (y) as a function of a set X of covariates. In addition, QR provides a conveniently powerful tool to estimate a conditional quantile assuming a linear form in the explanatory variables. The study will use the approach to multivariate quantile regression proposed by Carlier (2014).

Now we consider the Y endogenous variable as $\mathbf{R}^d$. The purpose of this is to explain the multivariate quantile of Y as a Brenier's map.

Set μ = uniform $([0,1]^d)$ and taking into account the correlation maximisation problem

Which is max $\{\mathbf{E}(V \cdot Y)$, Law $(V) = \mu\}$ (7)

For example, the quadratic transport problem

$$\inf \int_{R^d X R^d} |u - y|^2 \, \gamma(du, dy) \; \gamma \in \prod(\mu, \mathrm{Law}(Y)).$$

Brenier's theorem states that if Y is squared-integrable *d*-dimensional random variable,

there is a unique map of the form $T = \nabla_{\varphi}$ with φ convex on $[0,1]^d$ such that $\nabla_{\varphi \neq \mu}$ = Law(Y).

This map is referred to as the quantile function of Y

Then, the Polar factorisation is shown as

Y= ∇_{φ} (U), φ convex , U uniform

Conditional quantile

By taking a N-dimensional random vector X of independent variables,

v: = Law (X, Y), m: =Law (X), $v = m \otimes v^x$ where v^x is the law of Y given $X = x$.

Now we consider Q (x,.) = $\nabla_{\varphi}(x, u)$ as the optimal transport between u and v^x. $Q(x,.)$ then

the conditional multivariate quantile of Y given $X=x$.

In the presence of some irregularity assumptions on v^x, one can invert

Q (x,.): $Q(x,.)^{-1} = \nabla_{y\varphi}(x,.)^*$

(where the Legendre transform is taken for fixed x)

As in the unidimensional case, this U is uniformly distributed independently from X and solves:

$\max\{\mathbf{E}(V \cdot Y), \text{Law}(V) = \mu, V \perp X\}$. (8)

4 Empirical results

Table 2 Descriptive summary and list of commodities

Descriptive statistics						
		Mean	**S.D.**	**Min**	**Max**	**Obs**
Gold	Output	**238.57**	**120.20**	**81.10**	**428.80**	**29**
	Change in Sales	**-5.39**	**4.95**	**-16.20**	**3.00**	**29**
	MP Oil prices	**102.02**	**21.19**	**77.58**	**153.81**	**29**
	Exchange rates	**7.36**	**3.37**	**2.59**	**14.68**	**29**
	PPI	**60.78**	**33.13**	**18.39**	**120.80**	**29**
Coal	Output	**91.50**	**10.57**	**70.40**	**103.70**	**29**
	Change in Sales	**1.16**	**2.70**	**-3.60**	**6.80**	**29**
	MP Oil prices	**102.02**	**21.19**	**77.58**	**153.81**	**29**
	Exchange rates	**7.36**	**3.37**	**2.59**	**14.68**	**29**
	PPI	**60.78**	**33.13**	**18.39**	**120.80**	**29**
PGM's	Output	**82.21**	**18.96**	**51.50**	**112.30**	**29**
	Change in Sales	**3.11**	**11.88**	**-28.70**	**46.20**	**29**
	MP Oil prices	**102.02**	**21.19**	**77.58**	**153.81**	**29**
	Exchange rates	**7.36**	**3.37**	**2.59**	**14.68**	**29**
	PPI	**60.78**	**33.13**	**18.39**	**120.80**	**29**
Iron Ore	Output	**63.12**	**24.25**	**36.00**	**110.90**	**29**
	Change in Sales	**3.88**	**7.46**	**-11.20**	**16.40**	**29**
	MP Oil prices	**102.02**	**21.19**	**77.58**	**153.81**	**29**
	Exchange rates	**7.36**	**3.37**	**2.59**	**14.68**	**29**
	PPI	**60.78**	**33.13**	**18.39**	**120.80**	**29**
Manganese	Output	**54.08**	**32.24**	**21.20**	**135.20**	**29**
	Change in Sales	**5.70**	**17.73**	**-32.70**	**56.60**	**29**
	MP Oil prices	**102.02**	**21.19**	**77.58**	**153.81**	**29**
	Exchange rates	**7.36**	**3.37**	**2.59**	**14.68**	**29**
	PPI	**60.78**	**33.13**	**18.39**	**120.80**	**29**
Diamonds	Output	**129.59**	**30.23**	**75.10**	**191.60**	**29**
	Change in Sales	**1.21**	**15.61**	**-52.00**	**43.40**	**29**
	MP Oil prices	**102.02**	**21.19**	**77.58**	**153.81**	**29**
	Exchange rates	**7.36**	**3.37**	**2.59**	**14.68**	**29**
	PPI	**60.78**	**33.13**	**18.39**	**120.80**	**29**

Notes: S.D.: Standard Deviation. Min: Minimum. Max: Maximum. Obs: Number of observations

Notes: MP Oil prices: Mining Production Oil prices and PPI: Producer Price Index in domestic mining and quarry activities.

Source: Author's computation

Table 3: Correlation matrix statistics

	Correlation Matrix					
	Variables	**Output**	**Change in Sales**	**MP Oil prices**	**Exchange rates**	**PPI**
Gold	**Output**	1				
		(---)				
	Change in Sales	0.39	1			
		(0.04**)	(---)			
	MP Oil prices	-0.14	0.20	1		
		(0.46)	(0.29)	(---)		
	Exchange rates	-0.85	-0.18	0.45	1	
		(0.00***)	(0.36)	(0.02)**	(---)	
	PPI	-0.96	-0.27	0.37	0.89	1
		(0.00***)	(0.15)	(0.05*)	(0.00***)	(---)
Coal	**Output**	1				
		(---)				
	Change in Sales	-1.12	1			
		(0.55)	(---)			
	MP Oil prices	-0.05	-0.21	1		
		(0.78)	(0.28)	(---)		
	Exchange rates	0.76	-0.32	0.45	1	
		(0.00***)	(0.09*)	(0.02)**	(---)	
	PPI	0.86	0.30	0.37	0.89	1
		(0.00***)	(0.11)	(0.05*)	(0.00***)	(---)
PGM's	**Output**	1				
		(---)				
	Change in Sales	0.09	1			
		(0.66)	(---)			
	MP Oil prices	-0.26	0.16	1		
		(0.17)	(0.39)	(---)		
	Exchange rates	0.59	-0.03	0.45	1	
		(0.00***)	(0.87)	(0.02)**	(---)	
	PPI	0.67	-0.18	0.37	0.89	1
		(0.00***)	(0.36)	(0.05*)	(0.00***)	(---)
Iron Ore	**Output**	1				
		(---)				
	Change in Sales	0.16	1			
		(0.42)	(---)			
	MP Oil prices	0.45	-0.31	1		
		(0.01**)	(0.11)	(---)		
	Exchange rates	0.84	-0.01	0.45	1	
		(0.00***)	(0.95)	(0.02)**	(---)	
	PPI	0.97	0.09	0.37	0.89	1
		(0.00***)	(0.63)	(0.05*)	(0.00***)	(---)

TABLE 2 Continued.

Manganese	**Output**	1				
		(---)				
	Change in Sales	0.32	1			
		(0.09*)	(---)			
	MP Oil prices	0.60	-0.17	1		
		(0.00***)	(0.38)	(---)		
	Exchange rates	0.82	0.20	0.45	1	
		(0.00***)	(0.30)	(0.02)**	(---)	
	PPI	0.94	0.35	0.37	0.89	1
		(0.00***)	(0.06*)	(0.05*)	(0.00***)	(---)
Diamonds	**Output**	1				
		(---)				
	Change in Sales	0.26	1			
		(0.17)	(---)			
	MP Oil prices	-0.41	0.16	1		
		(0.03**)	(0.42)	(---)		
	Exchange rates	-0.30	0.03	0.45	1	
		(0.11)	(0.88)	(0.02)**	(---)	
	PPI	-0.38	0.03	0.37	0.89	1
		(-0.04**)	(0.86)	(0.05*)	(0.00***)	(---)

Notes: MP Oil prices: Mining Production Oil prices and PPI: Producer Price Index in domestic mining and quarry activities.

Notes: ***, **, * p values significant at the 1%, 5%, 10% level respectively.

Source: Author's computation

Table 2 reports the summary statistics of the six major mining sectors in South Africa from period 1990 to 2018. It is evident that these variables are comparable. The standard of deviation measures the dispersion around the mean and as a result, for all the sectors both exchange rates and changes in sales show smaller reasonable dispersion compared to others. The minimum and maximum values of the series are also given for each series under the column Min and Max, respectively.

Table 3 presents the correlation matrix which measures the degree or strength of the relationship of the coefficient. The presence of the conditional issues of multicollinearity can be seen in variables such as Producer Price Index (PPI) and Exchange Rates. On the other hand, the negative expected signs can be seen between the dependent variables and independent variables (exchange rate and PPI) for both gold and diamond sectors.

Table 4: Quantile regression estimation

Dependent Variable: Gold	Coefficient				S.E				P-values			
Quantile τ	**0.2**	**0.4**	**0.6**	**0.8**	**0.2**	**0.4**	**0.6**	**0.8**	**0.2**	**0.4**	**0.6**	**0.8**
Change in Sales	2.44	1.50	1.75	2.59	1.78	0.98	0.95	0.91	0.18	0.14	0.08*	0.01**
MP Oil prices	1.18	1.51	1.44	1.42	0.54	0.25	0.24	0.19	0.04**	0.00**	0.00***	0.00***
Exchange rates	-3.49	-3.60	-2.32	-3.02	3.13	3.47	2.61	1.92	0.27	0.31	0.38	0.12
PPI	-3.47	-3.46	-3.42	-3.30	0.32	0.33	0.26	0.22	0.00***	0.00***	0.00***	0.00***
DV GFC	41.78	32.31	24.20	25.79	21.39	20.19	21.08	14.44	0.06*	0.12	0.26	0.09*
β_0	356.87	324.72	329.58	338.93	64.08	24.96	23.79	19.01	0.00***	0.00***	0.00***	0.00***
Dependent Variable: Coal												
Change in Sales	0.57	0.62	0.43	0.60	0.30	0.33	0.38	0.36	0.06*	0.07*	0.27	0.11
MP Oil prices	-0.28	-0.27	-0.21	-0.23	0.05	0.05	0.06	0.06	0.00***	0.00***	0.00***	0.00***
Exchange rates	0.81	1.10	0.75	2.20	0.45	0.68	0.84	1.41	0.09*	0.12	0.38	0.09*
PPI	0.27	0.25	0.25	0.12	0.05	0.07	0.07	0.12	0.00***	0.00***	0.00***	0.30
DV GFC	-2.00	-2.76	-2.73	-4.33	3.24	3.63	3.69	3.82	0.54	0.46	0.47	0.27
β_0	94.33	98.82	92.56	90.78	4.92	4.80	4.32	5.62	0.00***	0.00***	0.00***	0.00***
Dependent Variable: PGM's												
Change in Sales	0.61	0.53	0.37	0.34	0.15	0.18	0.23	0.26	0.00***	0.01**	0.12	0.20
MP Oil prices	-0.64	-0.62	-0.59	-0.80	0.16	0.17	0.15	0.15	0.00***	0.00***	0.00***	0.00***
Exchange rates	0.46	0.82	1.87	0.71	1.22	1.32	1.29	2.86	0.71	0.54	0.16	0.81
PPI	0.47	0.44	0.38	0.64	0.11	0.12	0.13	0.37	0.00***	0.00**	0.01**	0.10
DV GFC	3.51	2.01	-2.06	-18.94	8.27	9.14	9.53	14.39	0.37	0.83	0.83	0.20
β_0	111.89	109.64	106.70	128.06	17.60	18.75	14.69	15.00	0.00***	0.00***	0.00***	0.00***
Dependent Variable: Iron ore												
Change in Sales	0.33	0.34	0.39	0.43	0.26	0.17	0.15	0.15	0.21	0.06*	0.02**	0.01**
MP Oil prices	0.18	0.11	0.09	0.24	0.08	0.07	0.06	0.08	0.04**	0.11	0.18	0.01**
Exchange rates	-0.19	-0.87	-1.19	-0.43	1.08	0.64	0.57	0.74	0.86	0.18	0.05*	0.57
PPI	0.60	0.71	0.76	0.79	0.14	0.07	0.07	0.07	0.00***	0.00**	0.00***	0.00***
DV GFC	-2.87	-8.67	-12.06	-13.67	8.56	5.73	4.74	4.24	0.74	0.14	0.02**	0.00***
β_0	4.49	12.86	15.71	-4.14	8.15	6.62	6.50	9.37	0.58	0.06*	0.02**	0.66
Dependent Variable: Manganese												
Change in Sales	0.17	0.24	0.23	0.22	0.09	0.11	0.09	0.09	0.06*	0.04**	0.02**	0.02**
MP Oil prices	0.42	0.51	0.61	0.62	0.14	0.09	0.07	0.07	0.01**	0.00***	0.00***	0.00***
Exchange rates	-1.94	-1.60	-1.81	-1.32	0.91	0.92	0.83	0.84	0.04**	0.10	0.04**	0.13
PPI	0.94	0.98	0.99	0.93	0.11	0.08	0.07	0.06	0.00***	0.00***	0.00***	0.00***
DV GFC	5.09	1.71	1.87	0.63	5.37	5.75	4.76	3.50	0.35	0.77	0.70	0.86
β_0	-37.44	-48.28	-54.99	-53.73	15.11	8.79	6.55	5.16	0.02**	0.00***	0.00***	0.00***
Dependent Variable: Diamond												
Change in Sales	0.67	0.83	1.07	0.82	0.23	0.37	0.42	1.68	0.01**	0.04**	0.02**	0.63
MP Oil prices	-0.11	-0.19	-0.44	-1.27	0.25	0.33	0.40	0.42	0.65	0.57	0.28	0.01**
Exchange rates	4.82	3.63	2.32	-5.40	1.82	2.05	3.06	6.06	0.01**	0.09*	0.45	0.38
PPI	-0.89	-0.72	-0.47	0.78	0.20	0.26	0.45	0.84	0.00***	0.01**	0.31	0.37

Table: 3 (Continued).												
DV GFC	64.31	57.20	45.82	-21.05	15.43	16.59	19.10	53.68	0.00***	0.00**	0.03**	0.70
β_0	142.74	155.17	180.00	272.84	25.70	33.60	40.76	41.20	0.00***	0.00**	0.00***	0.00***

Notes: ***, **, * p values significant at the 1%, 5%, 10% level respectively

Sourced: Author's computation

The quantile regression estimation outcomes for the indicated mining sectors are reported in Table 4. The above table shows the coefficients, standard error and the p-values for τ = 0.2, 0.4, 0.6 and 0.8. Moreover, for each sector, there are listed independent variables which include: change in sales, mining production oil prices, exchanges rates, Purchasing Price Index (PPI) and a dummy variable for the global financial crisis shock. The test results confirm that a change in mining sales has a relatively significant impact on total production for all the mining components for at least two quantiles from (τ) 0.2 to 0.8.

In terms of mining oil price, it is noticeable that the coefficient parameters are negative for the following commodities: Coal, PGMs and Diamonds while Gold, Manganese and Iron ore shows positive coefficient, irrespective of the quantile. In summary, this explains that a one percent increase in the mining oil price will result in a decrease in Coal, PGM and Diamond total output produced. Nkomo (2006) also shows that crude oil prices have contributed negatively towards the South African economy. Moreover, oil prices are determined by the demand and supply curve considering the value of rand/dollar exchange rates. According to Balcilar *et al.* (2014) oil price volatility will significantly reduce growth output such that the oil price inflationary impact will result in low growth.

Moving to exchange rates results, once again a one percent increase in rand/ dollar exchange rates will result in a decrease in gold, iron ore and manganese total output for all (τ) 0.2, 0.4, 0.6 and 0.8. The stronger dollar, or one percent increase in exchange rates (appreciation), is associated with a decrease of the total output of these commodities. Moreover, for the diamond sector, the coefficient parameter only becomes negative when (τ) = 0.8, while on both PGM and coal commodities, the coefficient parameter constantly shows a positive impact. These results were also confirmed by Lin and Wu (1992), Kandil and Mirzaie (2005), Berument and Pasaogullari (2003) and Jordaan and Nitshitenzhe (2015).

In terms of the global financial crisis parameter (dummy variable), the coal and iron ore total output is negatively affected by the shock that took place in 2008. This means that during the global financial crisis, the total output of these commodities substantially decreased but was

only statistically significant for Gold ((τ) =0.2 and 0.8), Diamond ((τ) = 0.2, 0.4 and 0.6) and Iron ore ((τ) = 0.6 and 0.8). These results are parallel to what Baxter (2011) found in his South African mining industry analyses.

Moving to the PPI, the estimated results show that there is a negative relationship and statistical significance appears in both the Gold and Diamond sectors. On the other hand, coal, PGMs, iron ore and manganese indicate a positive and significant relationship.

Table 5: Wald Test of the coefficient equality across different quantiles

Commodity	Test results	p-value
Gold	3.81	0.96
Coal	5.33	0.87
PGM's	6.40	0.78
Iron Ore	15.73	0.10
Manganese	3.77	0.96
Diamond	9.77	0.46

Sourced: Author's computation

The Wald test of the coefficient equality is reported in Table 5. The null hypothesis of coefficient equality is rejected at a level of 0.05, which confirms the graphical analysis. Not surprisingly, the results for all commodities' outputs provide insufficient evidence of asymmetry. In summary, the null hypothesis cannot be rejected because the p-value of each commodity is greater than 0.05 level of confidence.

5. Robustness Check

In statistics, robustness to distributional assumptions is important, so it is essential to emphasise that quantile regression inherits certain robustness properties of the ordinary sample quantiles. The estimates and the associated inference apparatus have an inherent distribution-free character since quantile estimation is influenced only by the local behaviour of the conditional distribution of the response near the specified quantile (Koenker 2005). The results of the QR coefficients and confidence intervals are presented in the Appendix. For all commodities, there is no sufficient evidence that the errors are independent and identically distributed and various levels of strength between the commodity total output as well as the regressors are depicted graphically in the Appendices.

6 Conclusion

The aim of the study is to measure the major aspects that contributed favourably and unfavourably towards the South African mining industry in order to pinpoint the mitigation action for a strategic improvement path. In order to grasp the complexity dynamics, the study employed the main contributors towards the mining industry which included changes in sales, mining production oil prices, exchange rates, producer price index(PPI) and the expected shock of the global financial meltdown. After using the quantile regression approach on the annual data collected from 1990 to 2018, the results were incongruous for each commodity output.

Based on the gold commodity output, the results indicated that the increase in gold revenue and mining production oil prices will positively alter the gold total output while Producer Price Index (PPI) negatively affects the total output in different conditional distributions. In addition, the dummy variable to address the global financial crisis analysis explains that the gold industry total output did not foresee the shock of the global financial meltdown. In terms of the South African coal industry, the outcome revealed that there is a negative relationship between coal total revenue and mining production oil prices, while the rand's depreciation will result in more revenue generated by the coal exporters. Moreover, the increase in Producer Price Index (PPI) is associated with more revenue in the coal industry.

Moving to PGMs, similar to the coal industry, there is a negative relationship between PGM total output and mining production oil prices, while Producer Price Index (PPI) shows a positive coefficient. With regard to to iron ore, the quantile regression results confirmed that all employed independent variables are statistically significant at the presented level of significance. This implies that exchange rates (weaker rand) and the global financial crisis shock contributed unfavourably towards the iron ore mining business. Furthermore, the studied literature indicated that South African exports most of its total output; however, the weaker rand will negatively affect the total revenue. Then, the iron ore model showed that mining production oil prices and Producer Price Index (PPI) are positively related to total iron ore output.

The studied literature indicated that manganese production has gradually increased throughout the period of study, and noticeably, after 2009 the manganese growth rate increased at a higher rate compared to previous years. The quantile regression results reported that there is an existence of a negative relationship between the exchange rate and manganese total output, which shows that the industry producers pay more attention to changes in the exchange rates.

On the other hand, an increase in total revenue, mining production oil prices and Producer Price Index (PPI) is associated with total output increases. The study expected the coefficient of global financial crisis dummy variable to be negative but the result yielded a positive and insignificant coefficient.

Based on the quantile regression, the results indicated that there is a negative significant nexus between diamond total output with mining production oil prices and Producer Price Index (PPI) in specified distribution quantiles. On the other hand, changes in revenue and exchanges rates directly related to total output production. The results of the coefficient global financial crisis dummy variable was expected to be negative but the result yielded a positive and significant coefficient.

7 Recommendations and Policy Implication

Further studies should make use of other empirical methodologies to evaluate the possible connection between mining industry total output and other recommendable events. Moreover, some studies' frameworks and results are country-orientated such as the existence of both absolute and comparative data. For example, an increase in oil prices is expected to necessarily affect the non Organization of the Petroleum Exporting Countries (OPEC) countries.

In general, the South African mining sectors export most of their total production output slice. In the case of rand weakness, this implies that the country requires more foreign currency than it is getting through sales of exports, and it supplies more of its own currency than foreigners demand for its products.

8 List of Acronyms

BIC: Bushveld Igneous Complex

CLS: Classical Least Squares

CVRD: Companhia Vale do Rio Doce

DMR: Department of Mineral Resource

GDP: Gross Domestic Production

FRED: Federal Reserve Economic Data

KIO: Kumba Iron Ore

KMR: Kudumane Manganese Resources

OPEC: Organization of the Petroleum Exporting Countries

PGM: Platinum Group Metals

PPI: Producer Price Index

QR: Quantile Regression

SAHO: South African History Online

UMK: United Manganese Kalahari

VECM: Vector Error Correction Model

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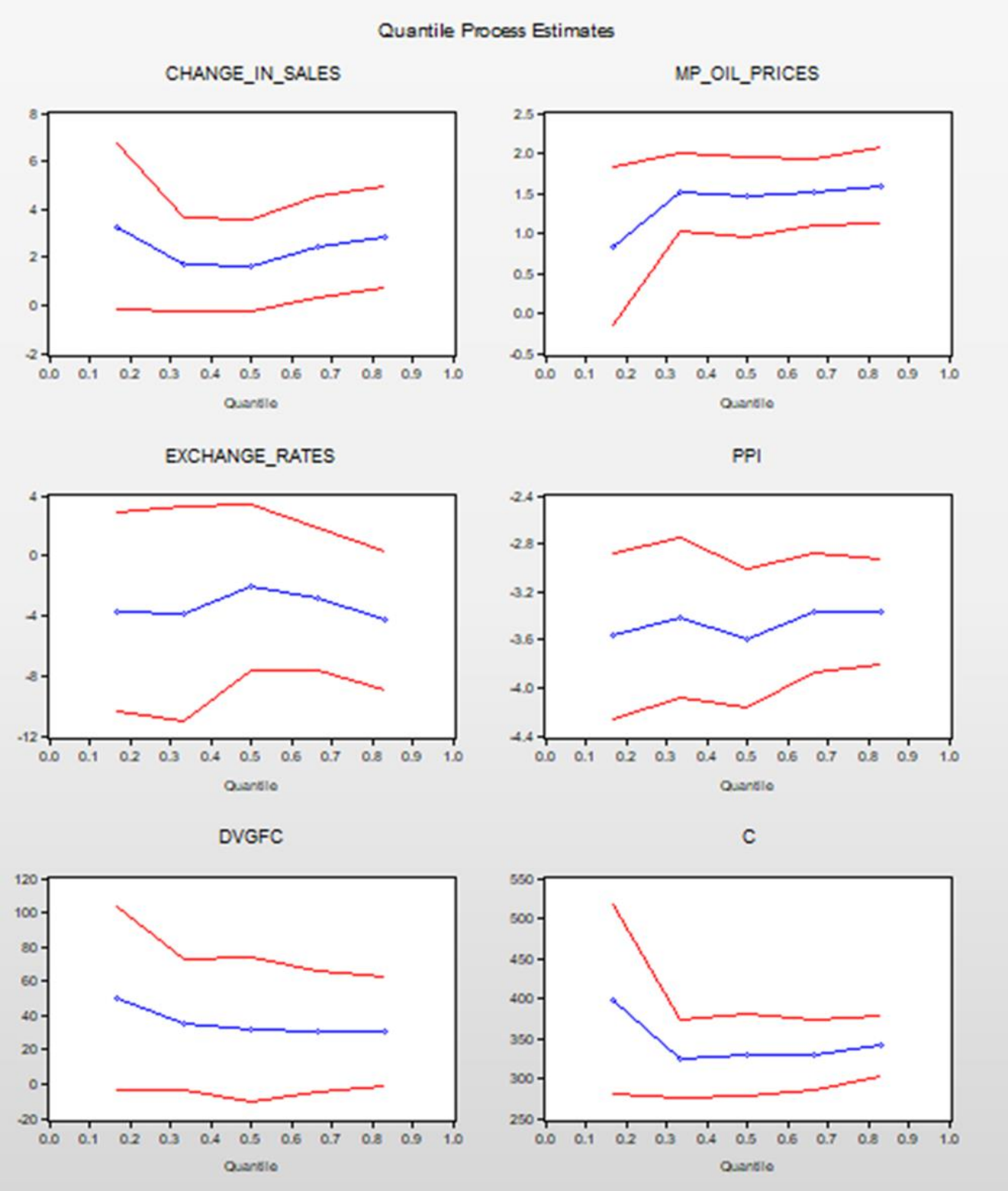
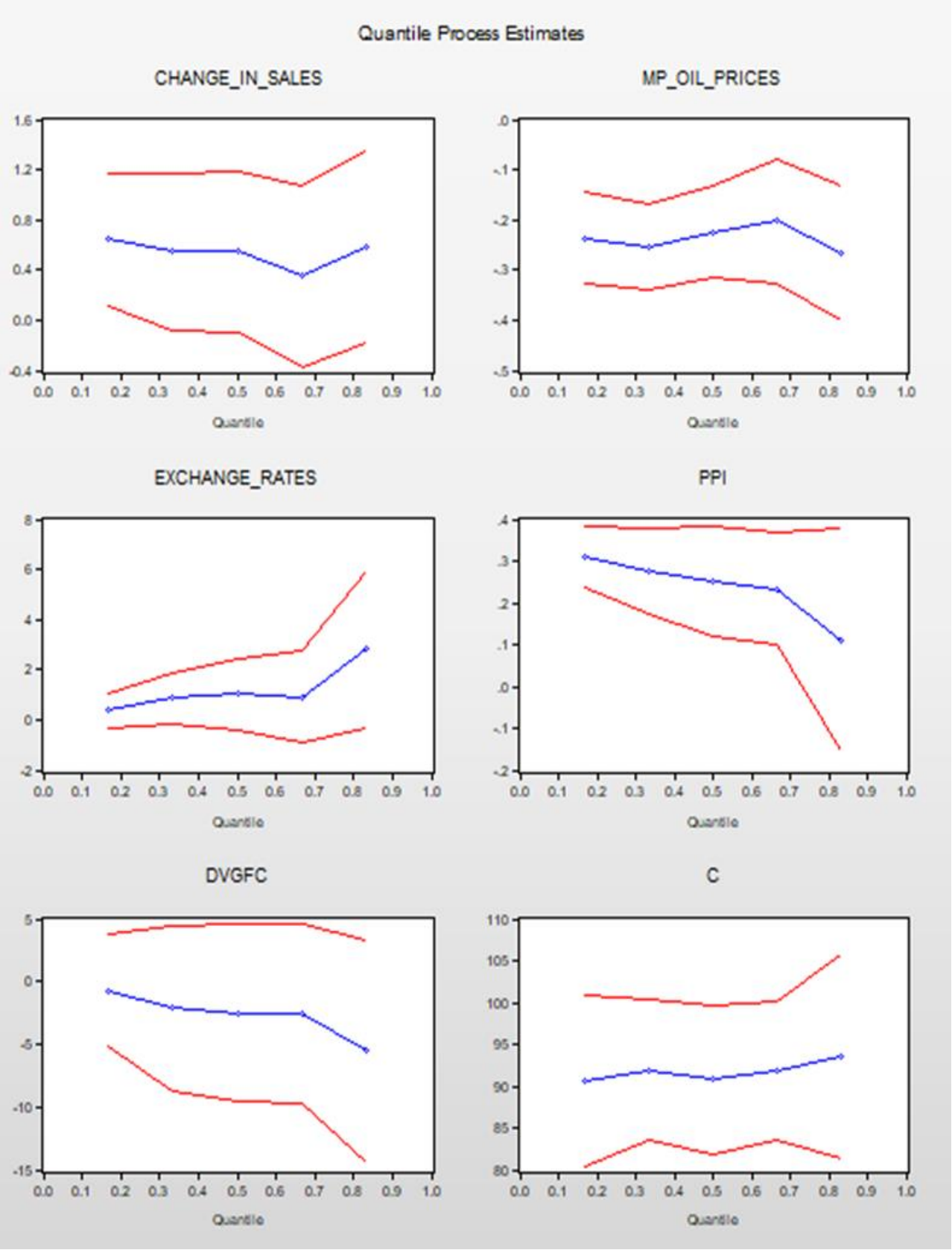
9 Appendix

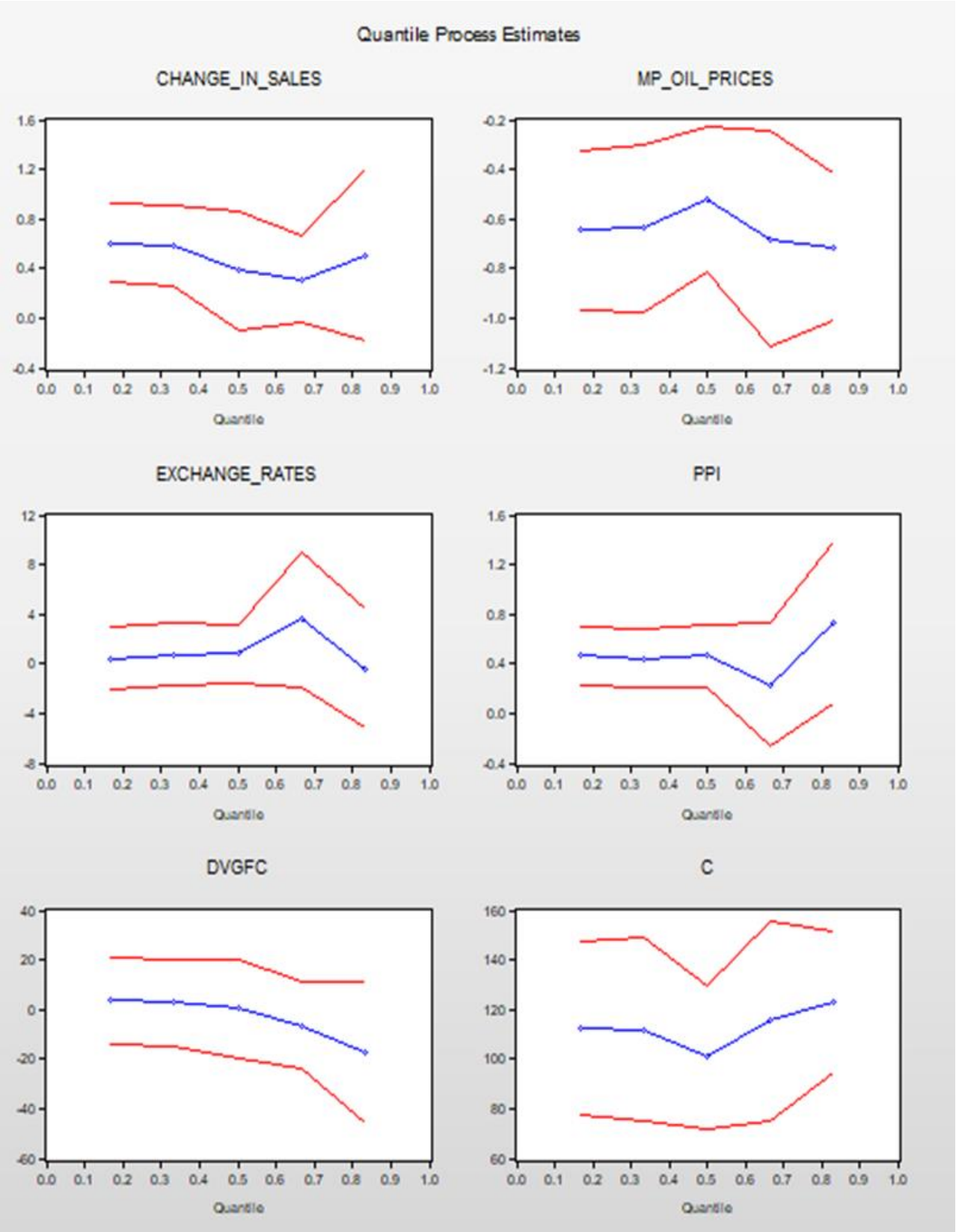
Graph 2. QR coefficients and confidence intervals as quantile varies from 0.2 to 0.8 (GOLD)



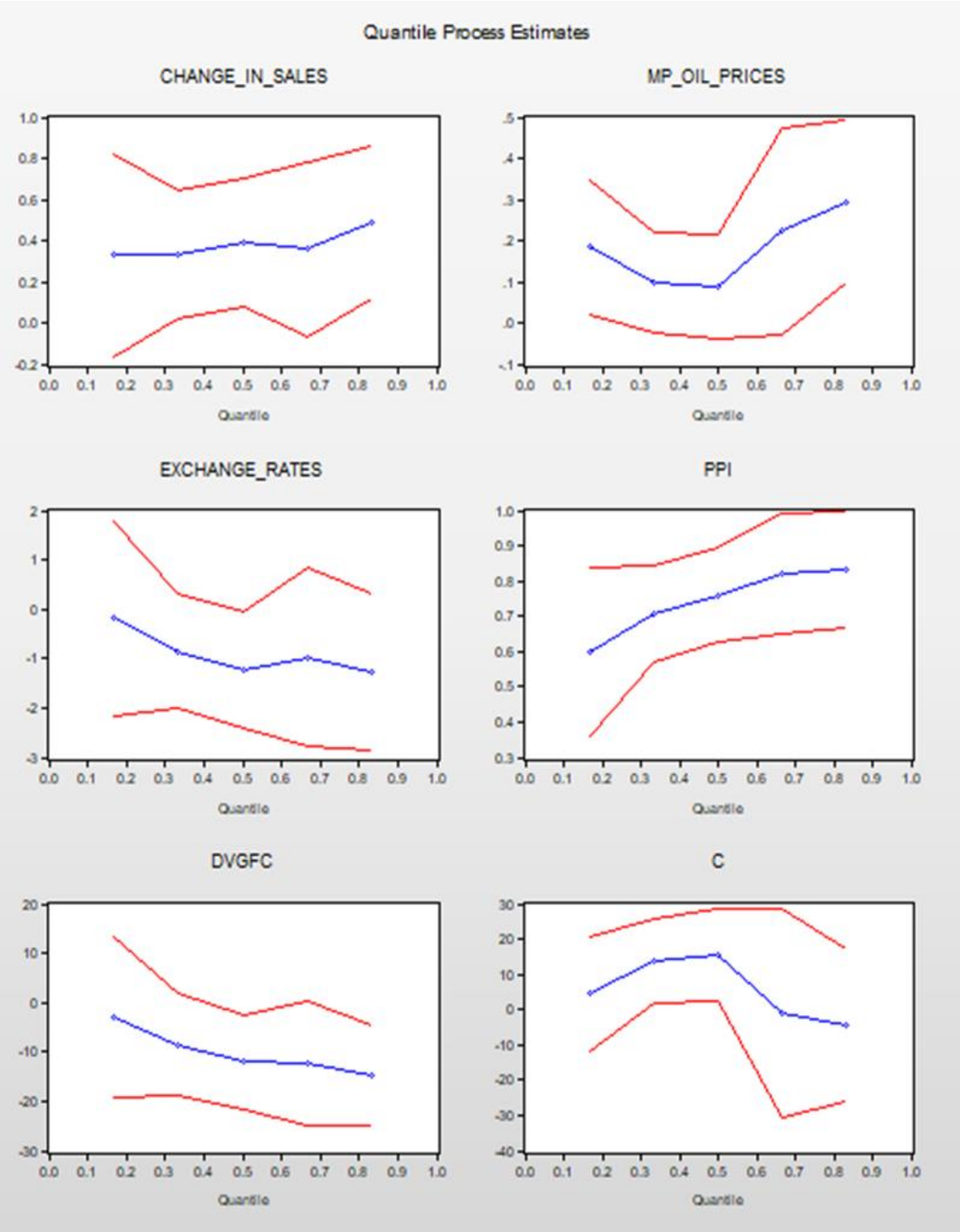
Graph 3. QR coefficients and confidence intervals as quantile varies from 0.2 to 0.8 (COAL)



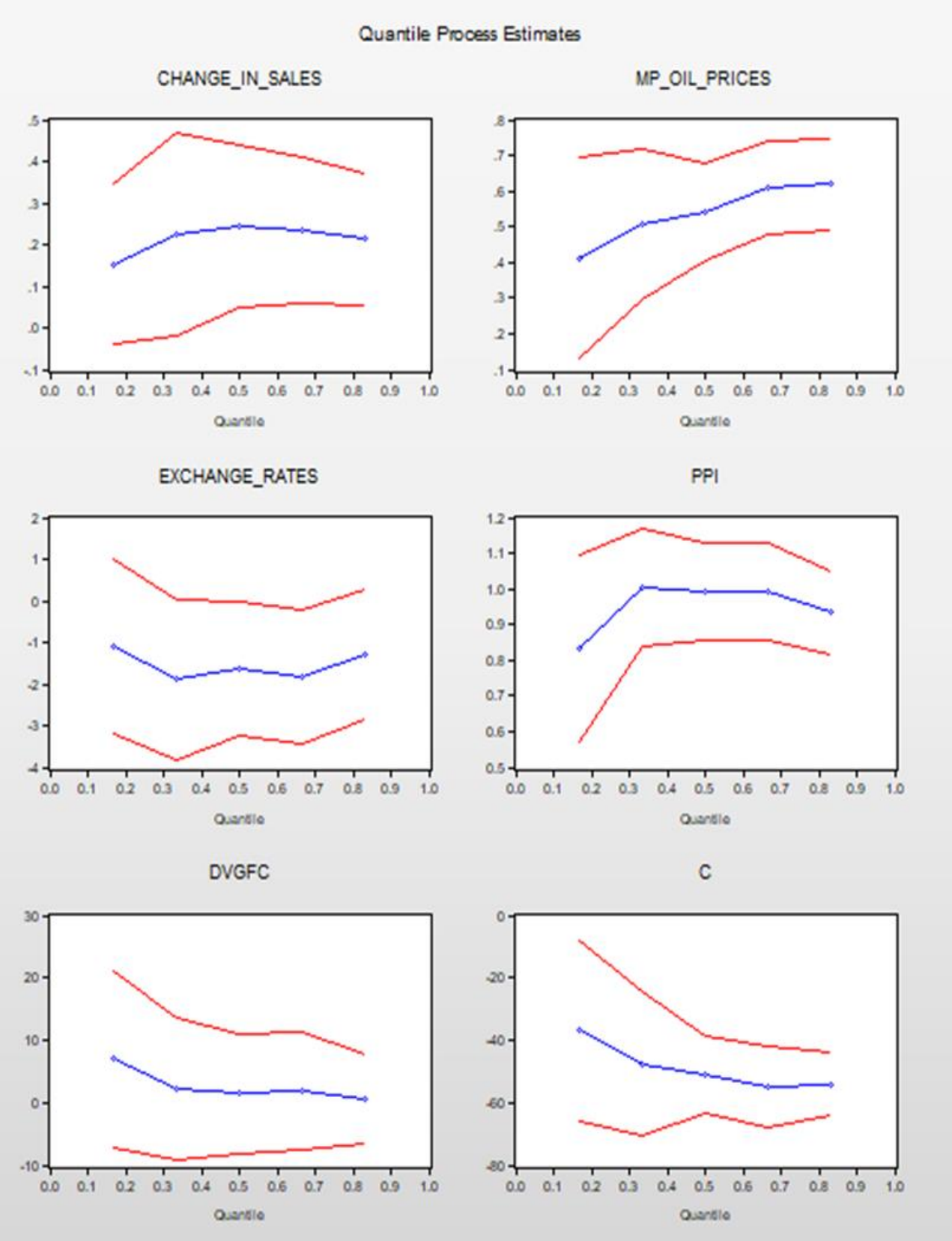
Graph 4. QR coefficients and confidence intervals as quantile varies from 0.2 to 0.8 (PGM'S)



Graph 5. QR coefficients and confidence intervals as quantile varies from 0.2 to 0.8 (IRON ORE)



Graph 6. QR coefficients and confidence intervals as quantile varies from 0.2 to 0.8 (MANGANSE)



Graph 7. QR coefficients and confidence intervals as quantile varies from 0.2 to 0.8 (DIAMOND)